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INTRODUCTION

Numerous research studies have shown the importance of communication in R&D organizations. The evidence strongly suggests that internal communication is positively related to R&D project performance (Allen, 1964; 1977; Baker et al, 1967; Goldhar, et al, 1976), all supporting the proposition that the best source of information for an R&D engineer is a colleague within his own organization. Good internal communication, therefore, assumes a paramount importance for the management of an R&D organization.

Other studies (Allen, et al, 1977; Dewhirst, et al, 1978; Hagstrom, 1965) have shown the relation between project performance and communication outside of the laboratory to be a function of whether the project involves research, development or technical service activities. In fact, the relation shifts from a positive to a negative one, depending on the nature of the project. While a strong, positive relationship between performance and external communication was found for research scientists and engineers, the relationship between performance and direct external contacts was negative for engineers who worked on product or process development projects. For these technology-oriented engineers, information was imported into the organization via a two-step process through a small number of specific individuals; i.e. the technological 'gatekeeper' phenomenon as identified by Allen and Cohen (1969).

Given these results, it is logical to inquire further how the nature of a project's task might affect the relative importance of internal communication. Along the spectrum of R&D activities in technology, different R&D functions have very different job requirements. Research tasks are aimed at a generation of new knowledge, whereas development tasks have as their objective the physical output of new products or processes, while technical service tasks meet very specific local needs of the organization (e.g., cost/performance improvements in existing products or operations). Moreover, the different individuals working

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on these different R&D tasks might also have different educational backgrounds, career objectives, and psychological dispositions. Given such marked differences in goals, and in personnel, it is reasonable to expect them to exhibit different patterns of information flow (Cf. Whitley and Frost, 1973).

While previous research studies have shown a strong overall positive relation between performance and internal communication, a number of questions still remain. For example, prior studies fail to show any significant relation between performance and the amount of communication amongst project members; yet a difference might exist in the pattern of communication interactions for the different R&D task types. Also, the relative importance of different internal information sources (e.g., different areas of the R&D laboratory or interfaces with marketing and production) might be different for the different task types. In addition, the appropriate role of the technical manager in information transfer might also depend on the nature of the project task. The present research is an attempt to differentiate among these internal communication requirements of projects in research, development, and technical service.

RESEARCH SETTINGS AND METHODS

This study was carried out at the R&D facility of a large American corporation. The laboratory's activities covered basic research and development of new products and technologies, as well as the assistance of marketing and manufacturing areas in product development and engineering. All of the company's products are related in that they share a common technology core. The basic technology facing the company may be characterized as being relatively mature and the laboratory has been a leading developer of that technology.

The R&D facility was isolated from the rest of the corporation and employed about 735 people. This study focused on all the professionals in the facility (n = 345). The laboratory was organized into seven groups or divisions. These

divisions were organized into separate project areas. The projects were stable work areas (rather than short term project groups in the team mission sense).

Technical Communication

A survey methodology was used to sample all work related communications over a period of fifteen weeks. Data were collected via questionnaires which were distributed on randomly selected days. The sampling days were chosen so that there would be an equal number of each of the different weekdays in the sample. At the end of each sampling day, every professional staff member in the laboratory was asked to recall each work-related communication contact, both within and outside the organization. Each respondent was asked not only to write down the names of those persons with whom he had work discussions, but also to check off the content of the conversation (i.e., problem definition or evaluation, idea generation, information location, and administrative matters). The first three of these categories will be aggregated as technical communication for the purposes of the present paper. As a result of travel, absences, etc., there was an average of 10 returns per respondent. After accounting for absences, the response rate was about 90 percent. Moreover, 68 percent of all the communications reported within the laboratory were mentioned by both parties.

The sociometric communication data were first aggregated over the fifteen weeks. Missing data (for example, due to vacation, out-of-town, non-returns, etc.) were taken into account by normalizing the reported communications to an average frequency per ten sampling days. The present study focuses on technical communication within the organization. In order to facilitate the analysis, aggregate measures of communication were classified according to the organizational affiliations of the discussion partners. More specifically, internal communications were categorized according to progressively larger but mutually exclusive organizational units; i.e.

- Intra-Project Communication - Communications with other professional members within one's immediate project.

- Communications With the Rest of the Laboratory - This is further broken down into two separate domains.
  -Intra-Divisional Communication (i.e. communications with other professional members outside of one's project but within the same division) and Inter-Division Communication (i.e. communications with professional members in other divisions).

- Communication with Other Parts of the Firm - Communications with people in the organizational operating units (i.e. people who are outside of the laboratory but within the company). Two domains of organizational communication are of specific interest in this study - marketing communication and production communication.

Project Task Type

To measure task type along the spectrum of R&D activities, respondents were asked to rate both the objectives as well as percentage time spent of their work efforts. Following the definitions used by Pelz and Andrews (1966), similar task categories were developed with the laboratory's management to form a task dimension covering the range of activities in the laboratory.

1. Basic Research: Work of a general nature intended to apply to a broad range of applications or to the development of a new knowledge about an area.

2. Applied Research: Work involving basic knowledge for the solution of a particular problem. The creation and evaluation of new concepts or components but not development for operational use.

3. Development: The combination of existing feasible concepts, perhaps with new knowledge, to provide a distinctly new product or process. The application of known facts and theory to solve a particular problem through exploratory study, design and testing of new components or systems.

4. Technical Service: Cost/performance improvements to existing products, processes or systems. Recombination, modification and testing of systems using existing knowledge. Opening new markets for existing products.

Using these definitions, respondents were asked to rate their task objectives on a 12 point scale, i.e., 3 degrees of refinement within each task categorization. Similarly, the task effort scale was measured by using an average of task characteristics weighted with the percentage time effort spent in each category or activities. The two scales were found to be highly correlated ($r = 0.91$, $p < .001$).

Task type was thus measured by simply averaging these two scales.

To measure project work characteristics, individual responses were pooled by projects. Bartlett's M test and a one way analysis of variance were used to check the appropriateness of pooling. If the variance within a project was significantly greater than the pooled variance ($p \geq .01$), then the project was not included in the analysis. Based on this method, project characteristics were obtained for 58 projects. The distribution of the task type characteristics fell into three distinguishable categories; i.e. research (14 projects), development (23 projects), and technical service (21 projects).

Project Performance

Data on project performance was obtained by interviewing the division managers (n = 8) and laboratory directors (n = 2). They were asked to evaluate all the projects with which they were technically familiar. Each project was thus independently rated by several managers on a seven point scale. A comparison of the rater means and intercorrelations indicated that one of the respondents biased his evaluations, and his responses were excluded. The scores of the remaining nine judges were then pooled to get project performance. Each project was rated by at least two judges with an average of 4.7 judges per project.

RESULTS

Differences in internal communication across projects of the three task types will be examined first. Next we will analyze the relation between performance and the various domains of internal communication. Finally, we will take a look at the role of the technical managers and its importance in the transfer of technical information.

Differences in Internal Communication Across Project Task Types

Intra-Project Communication: There is very little difference in the extent to which an individual project member communicates with fellow project members, in the three task areas (Figure 1). While there is slightly more internal communication for development projects this difference is far from significant statistically. The average project member had roughly 24 technically-oriented communications with other project members during the 10 sampling days or about 2.4 communications per day. The extent to which individuals differ in their intra-project communication does vary significantly, however (Table I). In research and technical service, project members do not differ quite as much in the extent to which they communicate among themselves, as do participants in development projects.

TABLE I

Variation Across Project Members in Technical Communication With the Project

Type of Project	N (Project Size > 2)	Coefficient of Variation $(\frac{\sigma}{u})$
research	13	0.45
development	21	0.58
technical service	15	0.42

Kruskal-Wallis ANOVA

$x^2 = 7.69 \quad p < 0.05$

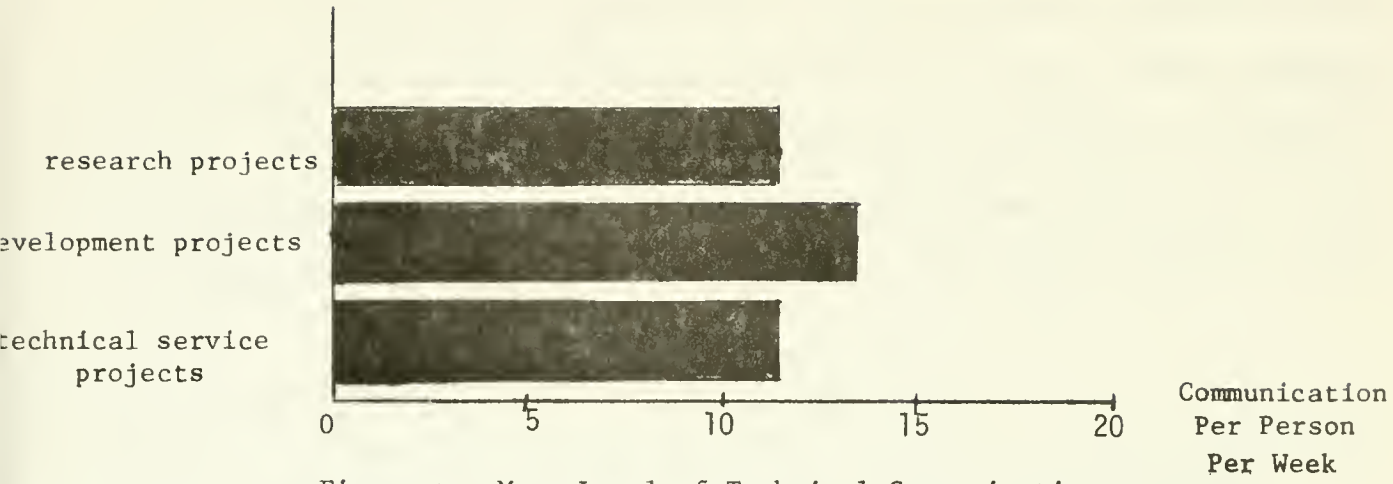

Figure 1. Mean Level of Technical Communication Within the Project

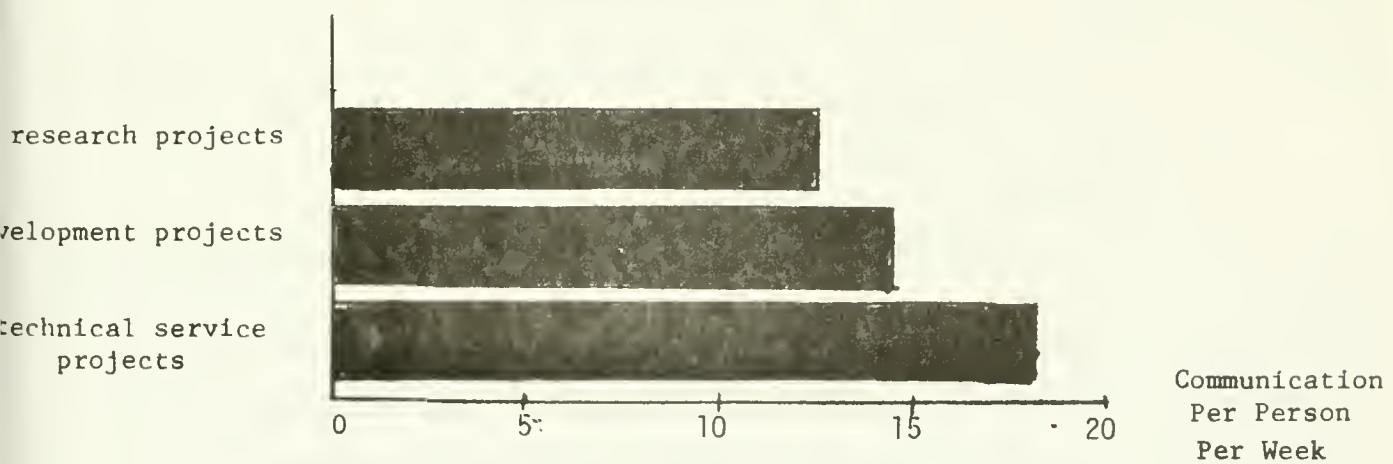

Figure 2. Mean Level of Technical Communication Within the Laboratory

Communication With the Rest of the Laboratory. Again, the three areas do not differ significantly in the extent of project members' communication (Figure 2). There is some apparent tendency for technical service people to communicate more with other laboratory staff. This difference is not significant, but whatever tendency there is, may be due to technical service projects drawing somewhat more heavily on the laboratory staff for technical support. In contrast, with intra-project communication, the three areas do not differ much in the way that laboratory communication is distributed among project members (Table II).

TABLE II

Variation Across Project Members in Technical Communication With Other Members of the Laboratory Staff

Type of Project	N (Project Size > 2)	Coefficient of Variation $(\frac{\sigma}{u})$
research	13	0.66
development	21	0.63
technical service	15	0.56

Kruskal-Wallis ANOVA

$x^2 = 1.19 \quad p < 0.50$

Communication With Other Parts of the Organization. Here there are very marked differences in the amount of communication (Figure 3). The average member of a research project communicates about once every two days with someone from parts of the firm outside of the R&D laboratory. On technical service projects, the

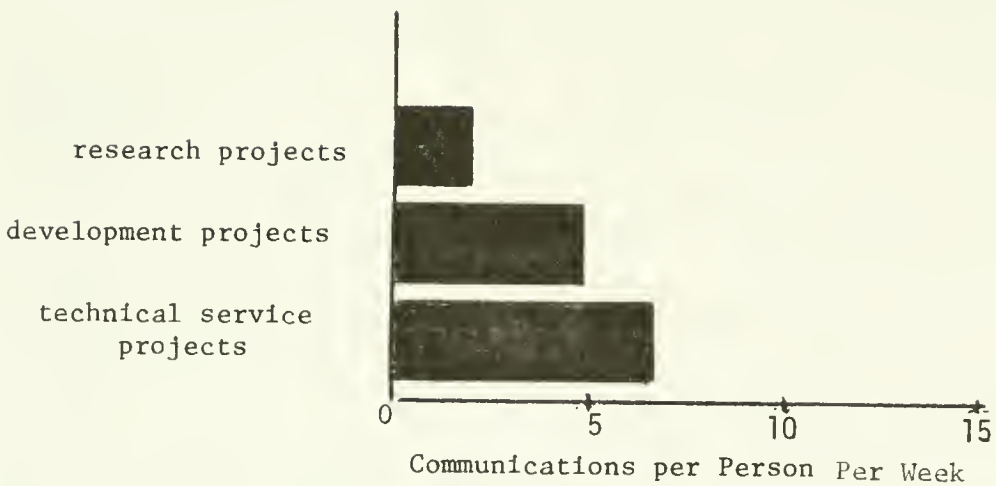

Figure 3. Mean Level of Technical Communication with Other Parts of the Firm

average is about 1.5 times per day. Development project members fall about mid-way between these extremes.

The variation across project members also differs among the three areas. Now the trend is in the opposite direction (Table III). Research projects show the greatest variation and technical service projects the least. Apparently, the responsibility for communication with other parts of the firm is assumed by specific personnel on research projects, while project members share the responsibility more equally in technical service projects.

TABLE III

Variation Across Project Members in Technical Communication With Parts of the Organization Outside of the R&D Laboratory

Type of Project	N (Project Size >2)	Coefficient of Variation $(\frac{\sigma}{u})$
research	13	1.30
development	21	1.01
technical service	15	0.66

Kruskal-Wallis ANOVA

$x^2 = 10.25 \quad p < 0.01$

Relationship With Performance

Communication Within the Project

In none of the three cases is there a significant relationship between project performance and degree to which project members communicate among themselves (Table VI). All three correlations are quite weak and fail to even approach

TABLE IV

Relation Between Performance and Technical Communication Among Project Team Members

Type of Project	N	r	p
research	14	0.05	N.S.
development	23	0.14	N.S.
technical service	21	0.17	N.S.

+r = Pearson Correlation
++p = Significance

statistical significance. Surprising as this may appear, it is not the first time that research has failed to uncover any relation between internal project communication and project performance. In a study of matched identical twin projects, Allen, et al, (1968) found that while members of higher performing project teams communicated more with other members of their laboratory, they did not communicate any more with fellow project members than did members of lower performing teams.

It was observed earlier that research, development and technical service projects differ significantly in the way in which communication is distributed among project members. Development projects showed the widest variance in internal communication. For development projects this turns out to be neither beneficial nor harmful (Table V). For research projects, however, the greater the variation, the poorer the performance of the project. Apparently, when one or a few project members dominate internal communication project performance suffers. For technical service projects, performance was found to relate positively with the variation in intra-project communication.

TABLE V

Relation Between Performance and the Variation ($\frac{\sigma}{u}$) Across Project Members' Communication Within the Project

Type of Project	N (Project Size > 2)	τ^+	p++
research	13	-0.50	0.03
development	21	-0.01	N.S.
technical service	15	0.28	0.11

+τ = Kendall's Tau

Communication With the Rest of the Laboratory

Since the laboratory was organized into different divisions around broad product technology areas, the physical and/or organizational separations might be important barriers to communication, and project members might play different roles in the information transfer process. Thus analysis of communications with colleagues within the laboratory will be divided into two sub-domains: intra-division communication and inter-division communication.

Looking first at intra-division communication, we find it to be important only in the case of development projects (Table VI & VII). Most of the research projects were contained within one of the divisions. The disciplines that they drew upon were varied, each project roughly describing a discipline area. As a result, there was somewhat less communication among projects in a division and no effect on performance. Research projects had to obtain their technical support from outside of the organization (Cf. Allen, et al, 1977; Dewhirst, et al, 1978). Technical service projects, on the other hand, had a very high level of intra-divisional communication, but again there was no effect on performance. Technical Service projects were organized in product area, rather than technology, divisions.

TABLE VI

Relation Between Performance and Communication With the Rest of the Laboratory

Type of Project	N	Intra-Division r	Intra-Division p	Inter-Division r	Inter-Division p
research	14	-0.17	N.S.	-0.34	0.12
development	23	0.31	0.08	0.09	N.S.
technical service	21	0.18	N.S.	-0.47	0.02

They therefore would find their technological support diffused through other groups as much as within their own. Only development projects were organized within technological/disciplinary divisions. The development project therefore obtained its technological support within its own division, to a greater degree than either research or technical service projects.

TABLE VII

Relation Between Performance and the Variation ($\frac{\sigma}{u}$) Across Project Members of Communication With the Rest of the Laboratory

Type of Project	N (Project Size > 2)	Intra-Division τ+	Intra-Division p	Inter-Division τ+	Inter-Division p
research	13	-0.17	N.S.	-0.20	N.S.
development	21	-0.25	0.06	-0.27	0.04
technical service	15	-0.02	N.S.	0.15	0.21

+τ = Kendall's Tau

In addition, not only is it beneficial for the people working on development projects to have more communication within the division, the results also show a negative correlation between performance and the variation across project members' communication with others in the divisions (Table VII) suggesting that specialization in role is not essential to intra-divisional communication.

Turning next to communication between divisions, it is quite surprising to see an inverse relation between performance of research projects and communication with other divisions in the laboratory (Table VI). This may be due to members of technical service projects seeking help from research, and interfering with the conduct of research projects. If this is true, the technical service projects aren't receiving much benefit either, since for them the relation between performance and inter-divisional communication is also inverse and even stronger. Only development projects fail to exhibit the inverse pattern. For them, it apparently makes no difference. There is no relation between performance and inter-divisional technical communication.

In surprising contrast with this finding is the discovery that it does make considerable difference, just how these communications are structured (Table VII). If there is a person, or subset of people who are primarily responsible for inter-divisional communication, the performance of research projects and product development projects will be impaired.

Communication With Other Parts of the Firm

As would be expected, development projects are strongly benefited by communication with other parts of the firm (Table VIII). It is surprising to see that technical service projects are not similarly helped. One would expect technical service to be strongly connected to marketing, and to produce better performance, the more closely they coordinated their activities with marketing. In fact, that does appear to be modestly true in the present case (Table IX).

TABLE VIII

Relation Between Performance and Communication with Other Parts of the Firm

Type of Project	N	r	p
research	14	-0.11	N.S.
development	23	0.46	0.01
technical service	21	0.06	N.S.

It is less important for technical service projects to communicate with manufacturing. In the case of development projects, it is important to communicate with both marketing and production (Table IX). This is a result that cannot be over-emphasized. There is a vast abundance (Myers & Marquis, 1969; Achilladelis, et al, 1971; Meadows & Marquis, 1968; Prakke, 1975) of evidence on this point. Product and process development projects must maintain a strong and constant awareness of market needs. This is much less important for research projects, which show no benefit from interaction with other parts of the firm.

TABLE IX

Relation Between Performance and Functional Areas Outside of the R&D Laboratory

		marketing		production		other	
Type of Project	N	r	p	r	p	r	p
research	14	0.12	N.S.	0.20	N.S.	0.21	N.S.
development	23	0.44	0.02	0.36	0.05	0.01	N.S.
technical service	21	0.20	N.S.	0.02	N.S.	0.21	N.S.

Not only is it important for members of development projects to communicate with other functions, but it is necessary for all members of these projects to maintain contact. No individual or subset of individuals should dominate this relationship. The greater the variation across project members in contact with other functions, the poorer the performance of the project (Table X).

TABLE X

Relation Between Performance and the Variation ($\frac{\sigma}{u}$) in Project Members' Communication with Other Parts of the Firm

Type of Project	N (Project Size > 2)	τ+	p
research	13	0.05	N.S.
development	21	-0.21	0.09
technical service	15	0.14	N.S.

+τ = Kendall's Tau

This would argue against such specialization in this communication as reported by Rhoades, et al, 1977. Controlling for the mean level of communication reduces this negative correlation to nearly zero. The data would no longer argue against a specialized role, but they do not lend support to such specialization, either.

Role of the Technical Manager

The results suggest that the relation between performance and internal communication changes according to whether the work involves research, development or technical service. Not only is performance related to the amount of

TABLE XI

Comparison of the Relation to Performance Between Mean Level of Communication and the Variation in Communication with Other Parts of the Firm (Development Projects)

correlation between project performance and:	τ	τ partial	variables partailled out
mean level of communication with other parts of the firm	0.31	0.31	variation in communication
variation across project members in communication with other parts of the firm	-0.21	-0.05	mean level of communication

communication by project members; but it also makes a great deal of difference in the way communication is managed by the group, e.g. in some instances individuals specialize in attending to specific sources of internal information, while in other cases the results suggested that it is important for all members of the project to maintain in contact with an area of the firm. Since the technical manager occupies a special and important role in each project, it is thus logical to explore his appropriate role in internal information transfer.

Role of the Technical Manager in Communications Within the Project

To assess the importance of the technical manager in intra-project communication, we tabulated the number of projects where the technical manager has the highest amount of within-project communication, and compared this observed frequency with the expected frequency based on a random model (where each project member has an equal chance of being the highest communicator). The results are broken down by high and low performance projects as well as the three task types, as shown in Table XI. For the high performance projects,

TABLE XII

Proportion of Total Projects Where Technical Manager Has the Highest Amount of Communication Within the Project

	Research Projects	
	High Performance Projects n=5	Low Performance Projects n=7
Observed Proportion	0.40	0.57
Expected Proportion*	0.23	0.21
Unexplained Proportion	0.17	0.36

	Development Projects	
	High Performance Projects n=9	Low Performance Projects n=11
Observed Proportion	0.67	0.45
Expected Proportion*	0.14	0.14
Unexplained Proportion	0.53	0.31

	Technical Service Projects	
	High Performance Projects n=9	Low Performance Projects n=5
Observed Proportion	0.89	0.60
Expected Proportion*	0.23	0.27
Unexplained Proportion	0.66	0.33

*Based on a random model

the results show that the managers of research projects did not exercise the most important role in communications within the project. As a matter of fact, their chance of being the leader in intra-project communication is only slightly higher than other project members (i.e. unexplained proportion = 0.17). The importance of the technical manager in intra-project communication increases as we go from research tasks to development and technical service tasks. Among the nine high performance technical service projects, eight technical managers were the highest communicators within their projects. For the low performance projects, there were no significant differences in the role of the technical manager for the three task types.

The results obtained here lend further support to the other findings: Although there was no significant relation between performance and the amount of intra-project communication, we found that it makes a great difference in the way that the total amount of communication within the project is distributed. For the research projects, it is important for each member of the project to participate equally and there is no need for the technical manager to assume a strong role. For the technical service projects, the relations are reversed, and it is beneficial for the technical manager to assume a strong role in communications within the project. While for the development projects, we found no significant relationships.

Role of the Technical Manager in Communications with the Rest of the Laboratory

Looking at the proportion of projects, in which the manager has the greatest amount of communication with other professionals in the laboratory (Table XIII), it can be seen that there is a major difference between development projects and those in research or technical service. For the nine high performance development projects, the technical managers had only about the same chance of being the highest communicator as their subordinates! This is contrasted with the much

TABLE XIII

Proportion of Total Projects Where Technical Manager Has the Highest Amount of Communication with the Rest of the Laboratory

	Research Projects	
	High Performance Projects n=5	Low Performance Projects n=7
Observed Proportion	0.60	0.33
Expected Proportion*	0.23	0.21
Unexplained Proportion	0.37	0.11

	Development Projects	
	High Performance Projects n=9	Low Performance Projects n=11
Observed Proportion	0.22	0.55
Expected Proportion	0.14	0.14
Unexplained Proportion	0.08	0.41

	Technical Service Projects	
	High Performance Projects n=9	Low Performance Projects n=5
Observed Proportion	0.78	0.60
Expected Proportion	0.23	0.27
Unexplained Proportion	0.55	0.33

higher chances for the technical managers in the low performance development projects. The results also show that the technical managers in the research projects and the technical service projects had much higher chances of being the leading communicator than their subordinates. For the technical service projects, we might suspect that there is a greater need for managers to assume an important coordination role in the organization and therefore they would have more communications. For the research projects, it is possible that managers in the high performance projects are more likely to be sought as "first referral consultants" in the laboratory, although this cannot be verified with the present data.

In the two previous sections, we found that internal communication with the rest of the laboratory was most important for the development engineers. Not only was there a significant positive correlation between performance and the amount of communication, it was also found to be important for all members of the project to have good interactions with other members of the laboratory. The results further show that the technical manager need not play any significant role in this channel of information transfer.

Role of the Technical Manager in Communications With the Rest of the Firm

Considering now the role of the project manager in communicating with other parts of the firm (Table XIV), we find that managers of more successful product development projects are less likely than their less successful counterparts to monopolize communication with other functional areas. This result is somewhat unexpected. Since the project manager might seem to be the most logical person to act as 'liaison' with people in the other organizational areas. However, together with the results obtained in the previous sections, this evidence confirms the importance of good communication with marketing and production for all the development engineers within the project but argues against the need of special roles, including that of the technical manager.

TABLE XIV

Proportion of Total Projects Where Technical Manager Has the Highest Amount of Communication with Other Parts of the Firm

	Research Projects			
	High Performance Projects n=5		Low Performance Projects n=7	
Observed Proportion	2/5	0.40	3/7	0.43
Expected Proportion *		0.23		0.21
Unexplained Proportion		0.17		0.22

	Development Projects			
	High Performance Projects n=9		Low Performance Projects n=11	
Observed Proportion	3/9	0.33	7/11	0.64
Expected Proportion*		0.14		0.14
Unexplained Proportion		0.19		0.50

	Technical Service Projects			
	High Performance Projects n=9		Low Performance Projects n=5	
Observed Proportion	5/9	0.56	2/5	0.40
Expected Proportion*		0.23		0.27
Unexplained Proportion		0.33		0.13

*Based on a random model

SUMMARY AND CONCLUSIONS

The single most important conclusion to be drawn from the study is that not all R&D functions are alike in the way they operate, nor should they be managed in the same way. This is a significant point for those doing research in the field, since the tendency has been to merely describe an organization, as an R&D laboratory, or its personnel as engineers and scientists. In fact, it makes a great deal of difference just what sort of work the organization and its staff are pursuing. Many have long realized the differences between university basic research scientists and engineers in industrial laboratories. Now it appears that the distinctions that must be made are even more subtle than that staff performing more research-oriented tasks in an industrial laboratory will behave very differently and have quite different needs from staff concerned with product and process development. These in turn, are quite different from those concerned with product modification and adaptation.

More specifically, the results indicate that our general concern for stimulating technical communication within the laboratory (Allen, 1970; Allen & Fusfeld, 1976) may be misplaced in the case of research and technical service staff. Only the product and process development engineers seem to really benefit from this form of interaction. Previous studies were primarily of engineers responsible for product development, and they concluded correctly that internal communication was strongly related to performance. Generalizing these results to the entire laboratory was, however, a mistake. We now know that the nature of the work makes a great deal of difference to the extent to which such results can be generalized. In a similar manner, we have long been aware of the importance of good communication between R&D and marketing (Cf. Prakke, 1975). The present study reinforces and reminds us of the obvious fact that such contact is really only important for product development staff. The performance of research projects is less affected by the research staff's relations with marketing.

Finally, we have the beginnings of some indications that very different supervisory styles are needed, depending upon the nature of the work. Research projects show the best performances when they are not dominated by any single individual, including the project manager. Technical service projects, on the other hand, perform better when the manager is more controlling and structures internal technical communication to a greater degree.

Much more will, of course, need to be done to investigate all of these areas. The present study is but a beginning and we must be careful in generalizing from it. Nevertheless, it is an interesting beginning and should open fruitful new areas for research.

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